```
┌─────────────────────────────────────┐
│                                     │      102
│   Define primitive event types      │
│                                     │
└─────────────────────────────────────┘
                  │
                  ▼
┌─────────────────────────────────────┐
│  Define combinations of the         │      104
│  primitive event types as a         │
│  compound event type                │
└─────────────────────────────────────┘
                  │
                  ▼
┌─────────────────────────────────────┐
│  Input the primitive event          │
│  occurrences, such occurrences      │
│  being specified as the set of      │      106
│  temporal intervals over which      │
│  a given primitive event type       │
│  is true, wherein the sets of       │
│  temporal intervals are specified   │
│  as smaller sets of spanning        │
│  intervals, each spanning interval  │
│  representing a set of intervals    │
└─────────────────────────────────────┘
                  │
                  ▼
┌─────────────────────────────────────┐
│  Compute the compound event         │      108
│  occurrences, such occurrences being│
│  specified as the set of temporal   │
│  intervals over which the compound  │
│  event type is true, wherein the sets│
│  of temporal intervals are specified│
│  as smaller sets of spanning intervals,│
│  each spanning interval representing │
│  a set of intervals                 │
└─────────────────────────────────────┘
```

FIG. 1

Label primitive subexpressions of Φ with spanning intervals that represent the sets of intervals over which the corresponding primitive event types hold

Are there any subexpressions that have not been labeled with sets of spanning intervals?

No → Stop: output the set of spanning intervals that label the whole (root) expression Φ

Yes ↓

Let Φ' be some subexpression of Φ such that Φ' is not labeled with sets of spanning intervals but for which all subexpressions $\Phi_1'', ..., \Phi_n''$ of Φ' are labeled with sets of spanning intervals

Apply the appropriate formula for $\varepsilon(M, \Phi')$ using the subroutines $\langle i \rangle$, $i_1 \bigcap i_2, \neg i$, $\mathbf{SPAN}(i_1, i_2), \mathcal{D}(r, i)$, and $\mathcal{I}(i, r, j)$ to compute a set of spanning intervals to label Φ'

FIG. 2

$$x = y \quad \triangleq \quad \overline{x = y}$$

$$\textsc{Supported}(x) \quad \triangleq \quad \overline{\neg\textsc{Grounded}(x)}$$

$$\textsc{RigidlyAttached}(x,y) \quad \triangleq \quad (\exists r)\textsc{Rigid}(x,y,r)$$

$$\textsc{Supports}(x,y) \quad \triangleq \quad \overline{\left(\begin{array}{l} \neg\textsc{Grounded}(y) \wedge \\ \neg\textsc{Stable}(P \setminus \{x\}, M \cup \{\textsc{Grounded}(z) \mid \neg\textsc{RigidlyAttached}^*(z,y)\}) \end{array} \right)}$$

$$\textsc{Contacts}(x,y) \quad \triangleq \quad \overline{\textsc{Touches}(x,y) \wedge x \bowtie y}$$

$$\textsc{Attached}(x,y) \quad \triangleq \quad \overline{(\exists r)\textsc{Rigid}(x,y,r) \vee \textsc{Revolute}(x,y,r)}$$

FIG. 3

$$\text{PickUp}(x, y, z) \triangleq \left\{ \begin{array}{l} \neg\Diamond x = y \wedge \neg\Diamond z = x \wedge \neg\Diamond z = y \wedge \\ \text{Supported}(y) \wedge \neg\Diamond\text{Attached}(x, z) \wedge \\ \left\{ \begin{array}{l} \left[\begin{array}{l} \neg\Diamond\text{Attached}(x, y) \wedge \neg\Diamond\text{Supports}(x, y) \wedge \\ \text{Supports}(z, y) \wedge \\ \neg\Diamond\text{Supported}(x) \wedge \neg\Diamond\text{Attached}(y, z) \wedge \\ \neg\Diamond\text{Supports}(y, x) \wedge \neg\Diamond\text{Supports}(y, z) \wedge \\ \neg\Diamond\text{Supports}(x, z) \wedge \neg\Diamond\text{Supports}(z, x) \end{array} \right] ; \\ \left[\text{Attached}(x, y) \vee \text{Attached}(y, z) \right]; \\ \left[\begin{array}{l} \text{Attached}(x, y) \wedge \text{Supports}(x, y) \wedge \\ \neg\Diamond\text{Supports}(z, y) \wedge \\ \neg\Diamond\text{Supported}(x) \wedge \neg\Diamond\text{Attached}(y, z) \wedge \\ \neg\Diamond\text{Supports}(y, x) \wedge \neg\Diamond\text{Supports}(y, z) \wedge \\ \neg\Diamond\text{Supports}(x, z) \wedge \neg\Diamond\text{Supports}(z, x) \end{array} \right] \end{array} \right\} \end{array} \right\}$$

$$\text{PutDown}(x, y, z) \triangleq \left\{ \begin{array}{l} \neg\Diamond x = y \wedge \neg\Diamond z = x \wedge \neg\Diamond z = y \wedge \\ \text{Supported}(y) \wedge \neg\Diamond\text{Attached}(x, z) \wedge \\ \left\{ \begin{array}{l} \left[\begin{array}{l} \text{Attached}(x, y) \wedge \text{Supports}(x, y) \wedge \\ \neg\Diamond\text{Supports}(z, y) \wedge \\ \neg\Diamond\text{Supported}(x) \wedge \neg\Diamond\text{Attached}(y, z) \wedge \\ \neg\Diamond\text{Supports}(y, x) \wedge \neg\Diamond\text{Supports}(y, z) \wedge \\ \neg\Diamond\text{Supports}(x, z) \wedge \neg\Diamond\text{Supports}(z, x) \end{array} \right] ; \\ \left[\text{Attached}(x, y) \vee \text{Attached}(y, z) \right]; \\ \left[\begin{array}{l} \neg\Diamond\text{Attached}(x, y) \wedge \neg\Diamond\text{Supports}(x, y) \wedge \\ \text{Supports}(z, y) \wedge \\ \neg\Diamond\text{Supported}(x) \wedge \neg\Diamond\text{Attached}(y, z) \wedge \\ \neg\Diamond\text{Supports}(y, x) \wedge \neg\Diamond\text{Supports}(y, z) \wedge \\ \neg\Diamond\text{Supports}(x, z) \wedge \neg\Diamond\text{Supports}(z, x) \end{array} \right] \end{array} \right\} \end{array} \right\}$$

$$\text{Stack}(w, x, y, z) \triangleq \left[\begin{array}{l} \neg\Diamond z = w \wedge \neg\Diamond z = x \wedge \neg\Diamond z = y \wedge \\ \text{PutDown}(w, x, y) \wedge \text{Supports}(z, y) \wedge \neg\text{Attached}(z, y) \end{array} \right]$$

$$\text{Unstack}(w, x, y, z) \triangleq \left[\begin{array}{l} \neg\Diamond z = w \wedge \neg\Diamond z = x \wedge \neg\Diamond z = y \wedge \\ \text{PickUp}(w, x, y) \wedge \text{Supports}(z, y) \wedge \neg\text{Attached}(z, y) \end{array} \right]$$

$$\text{Move}(w, x, y, z) \triangleq \neg\Diamond y = z \wedge \left[\text{PickUp}(w, x, y); \text{PutDown}(w, x, z) \right]$$

$$\text{Assemble}(w, x, y, z) \triangleq \text{PutDown}(w, y, z) \wedge_{\{<\}} \text{Stack}(w, x, y, z)$$

$$\text{Disassemble}(w, x, y, z) \triangleq \text{Unstack}(w, x, y, z) \wedge_{\{<\}} \text{PickUp}(x, y, z)$$

FIG. 4
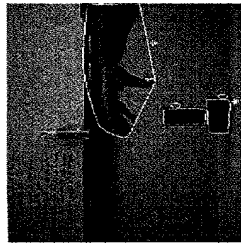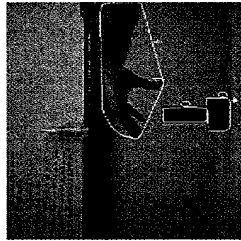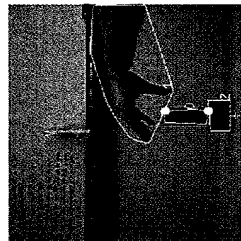
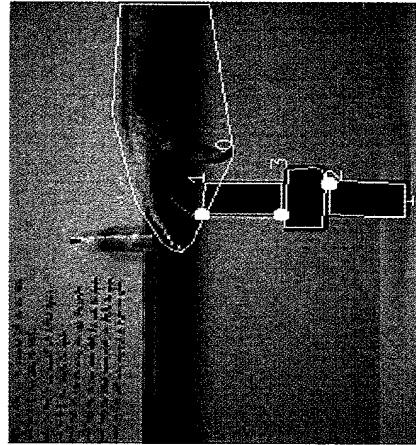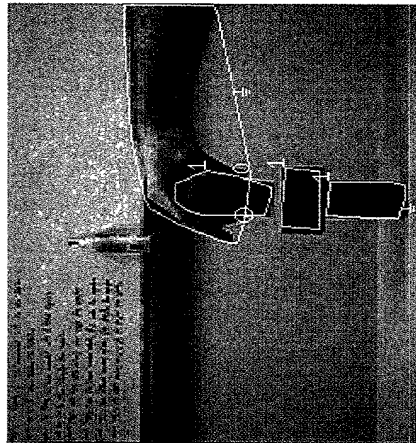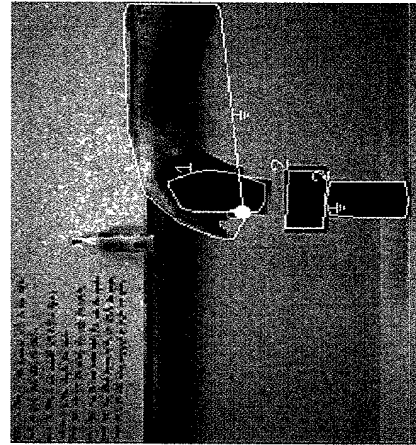frame 0   frame 1   frame 2   frame 13   frame 14   frame 20
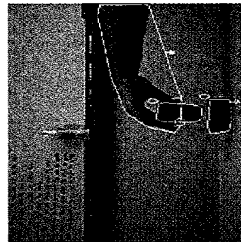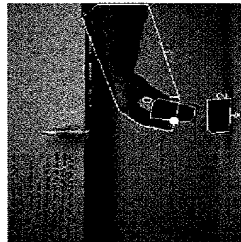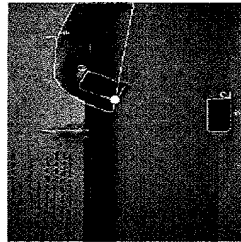
FIG. 5A
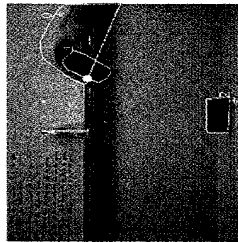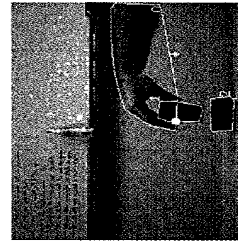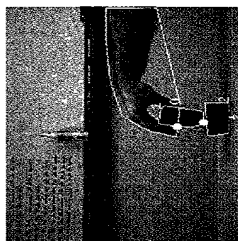
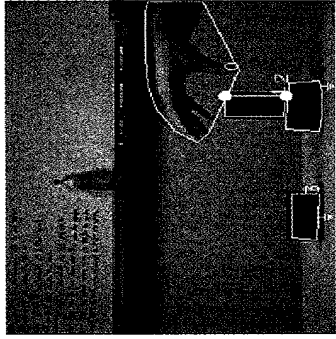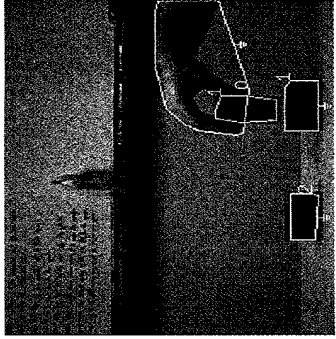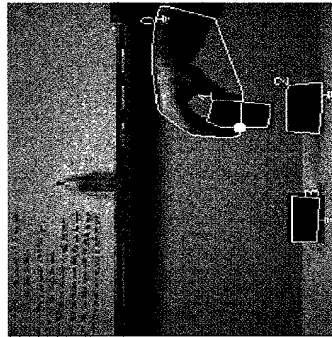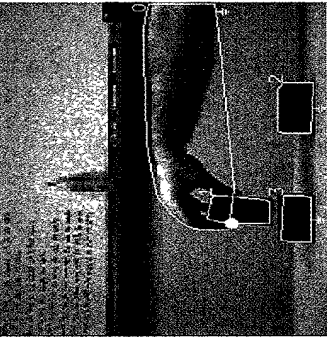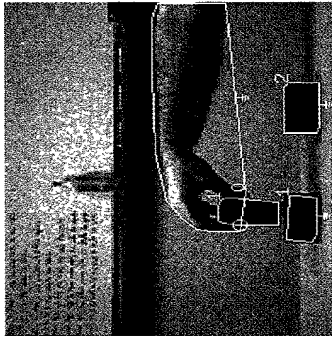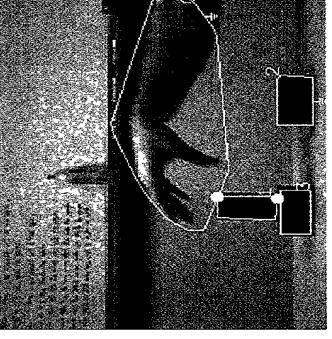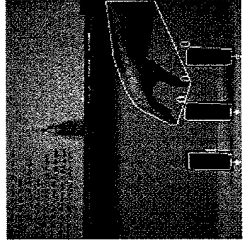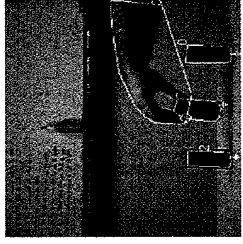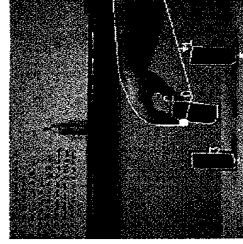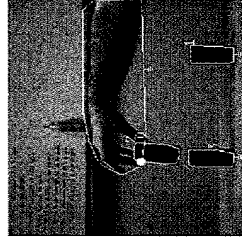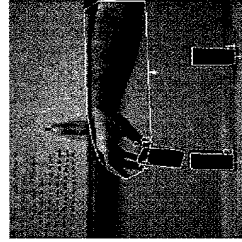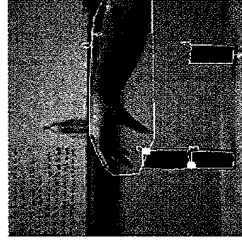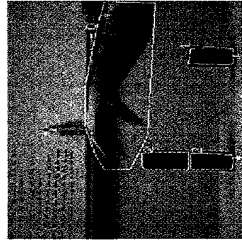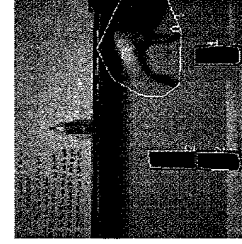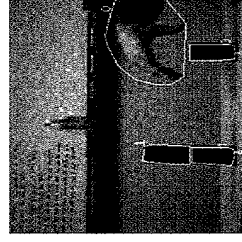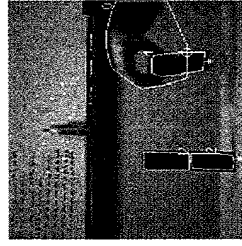frame 1   frame 13   frame 14   frame 22   frame 23   frame 27
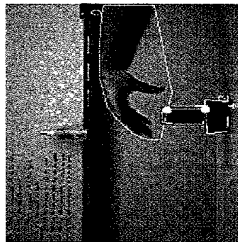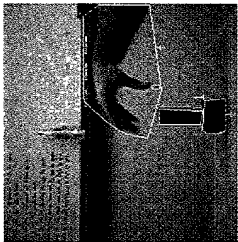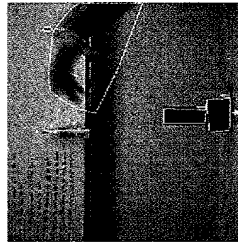
FIG. 5B

```
(PICK-UP MOVING RED GREEN)@{[[0,1],[14,22]]}

(SUPPORTED? RED)@{[[0:22]]}
(SUPPORTED? MOVING)@{[[1:13]], [[24:26]]}
(SUPPORTS? RED MOVING)@{[[1:13]], [[24:26]]}
(SUPPORTS? MOVING RED)@{[[13:22]]}
(SUPPORTS? GREEN RED)@{[[0:14]]}
(SUPPORTS? GREEN MOVING)@{[[1:13]]}
(CONTACTS? RED GREEN)@{[[0:2]], [[6:14]]}
(ATTACHED? RED MOVING)@{[[1:26]]}
(ATTACHED? RED GREEN)@{[[1:6]]}
```

FIG. 6A

```
(PUT-DOWN MOVING RED GREEN)@{[[0,14],[23,32]]}

(SUPPORTED? MOVING)@{[[14:23]]}
(SUPPORTED? RED)@{[[0:32]]}
(SUPPORTS? MOVING RED)@{[[0:14]]}
(SUPPORTS? RED MOVING)@{[[14:23]]}
(SUPPORTS? GREEN MOVING)@{[[14:23]]}
(SUPPORTS? GREEN RED)@{[[14:32]]}
(CONTACTS? RED GREEN)@{[[22:32]]}
(ATTACHED? MOVING RED)@{[[0:23]]}
(ATTACHED? RED GREEN)@{[[14:22]]}
```

FIG. 6B

frame 3

frame 11

frame 12

frame 23
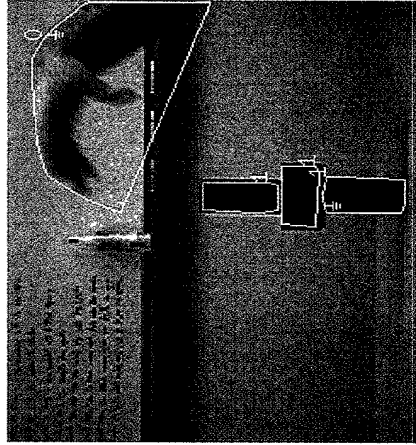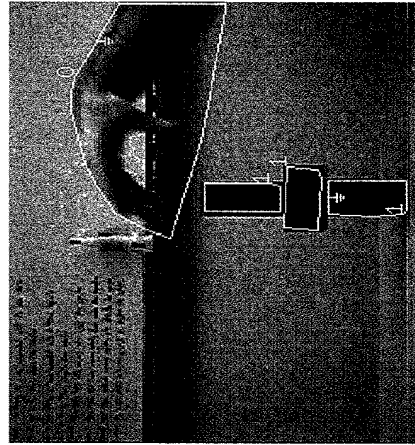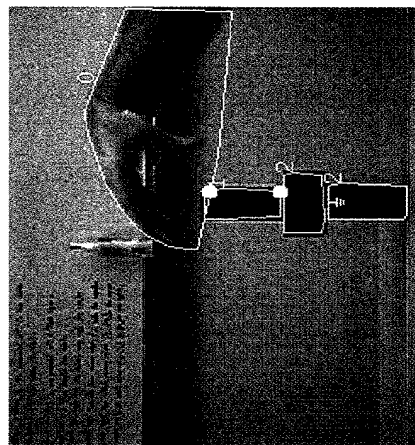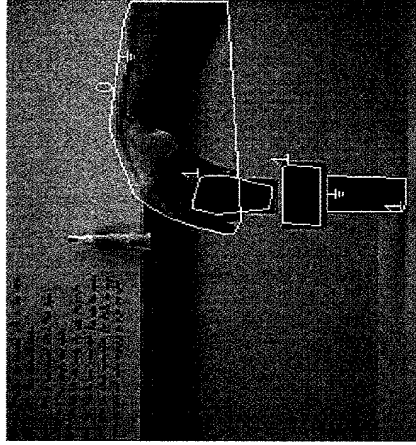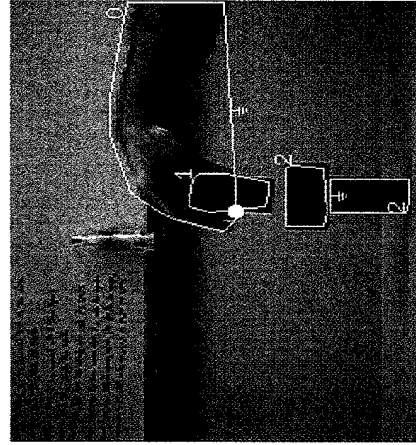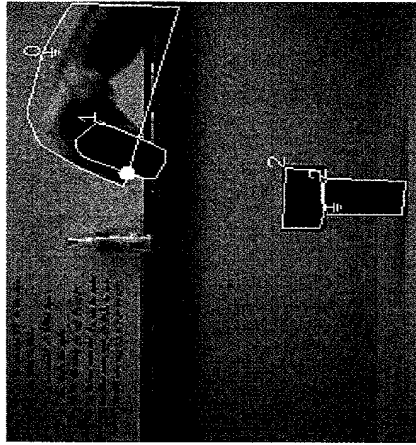
frame 24

frame 26

FIG. 7A
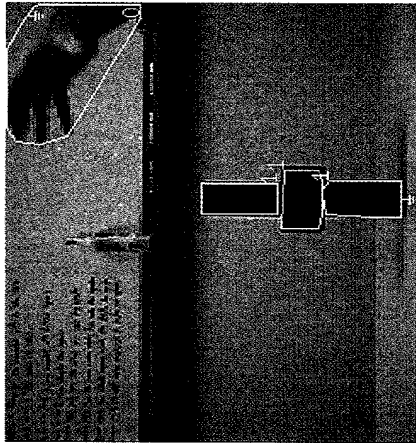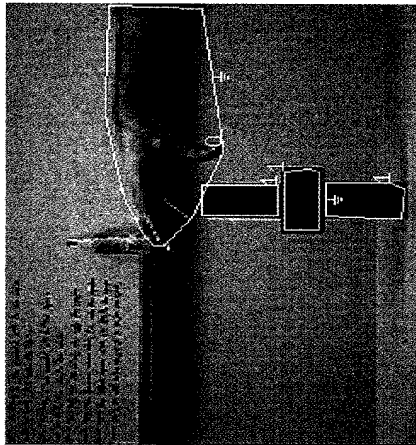
frame 1   frame 10   frame 11

frame 24   frame 25   frame 29
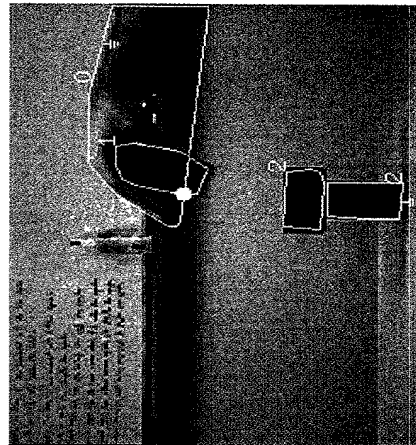
FIG. 7B
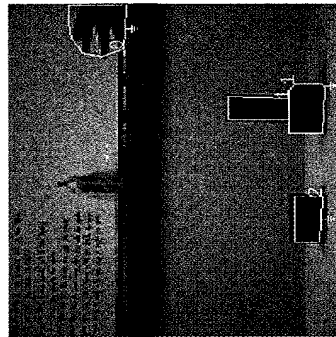
frame 0
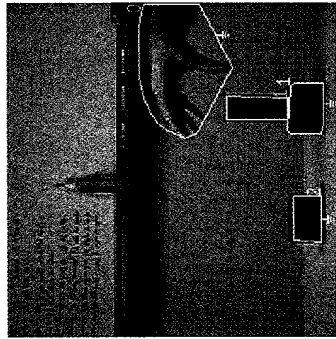
frame 8

frame 9

frame 16

frame 17

frame 33

frame 34

frame 45
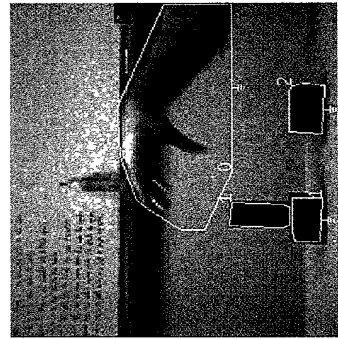
frame 46
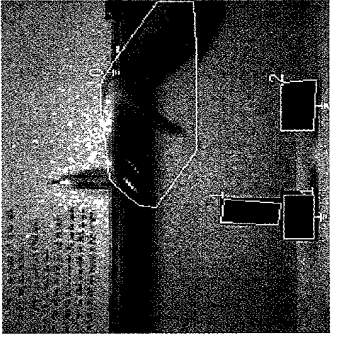
frame 47

FIG. 7C
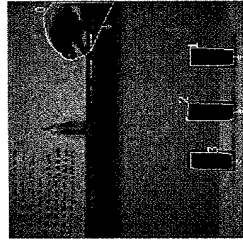
frame 18
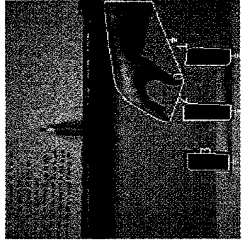
frame 17

frame 10

frame 9

frame 0

frame 46
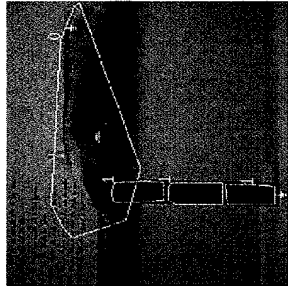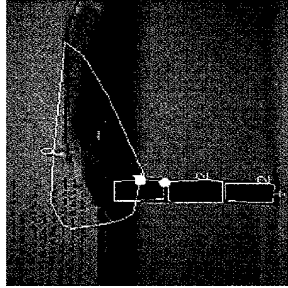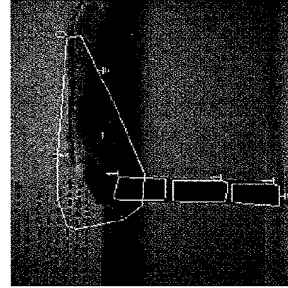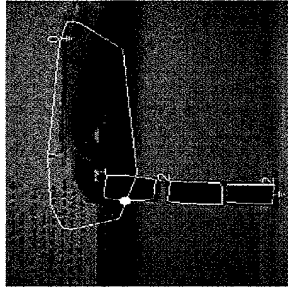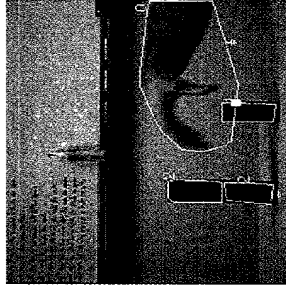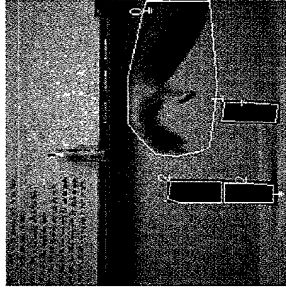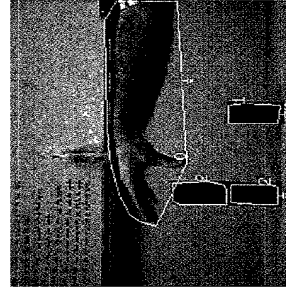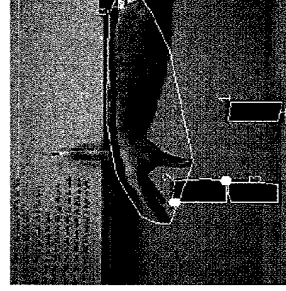
frame 41

frame 40

frame 33

frame 32
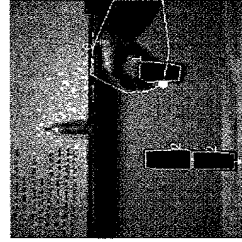
frame 68
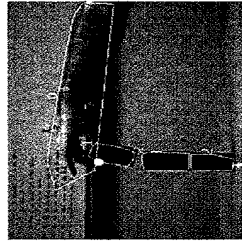
frame 67
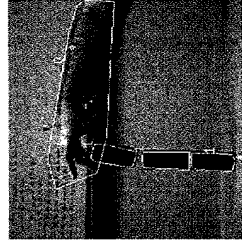
Frame 57
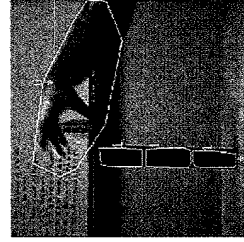
frame 56

frame 47

frame 80

FIG. 7D

frame 18 · frame 19 · frame 22 · frame 23
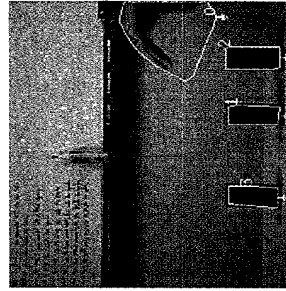
frame 49 · frame 50 · frame 56 · frame 57
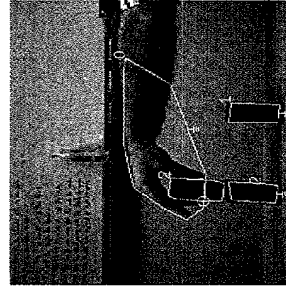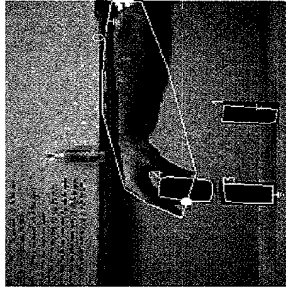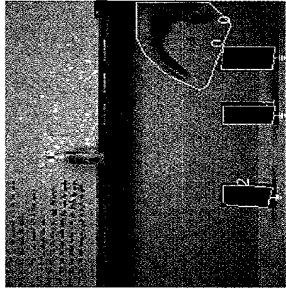
frame 62 · frame 63 · frame 87 · frame 88

FIG. 7E

```
(PUT-DOWN MOVING RED BLUE)@([[0,12],[24,30])}
(STACK MOVING RED BLUE GREEN)@([[0,12],[24,30])}

(SUPPORTED? MOVING)@{[[13:24]]}
(SUPPORTED? RED)@{[[0 30])}
(SUPPORTED? BLUE)@{[[0:30]]}
(SUPPORTS? MOVING RED)@{[[0:12]]}
(SUPPORTS? RED MOVING)@{[[13:24]]}
(SUPPORTS? RED BLUE)@{[[19:20]], [[21:22]]}
(SUPPORTS? GREEN MOVING)@{[[19:20]], [[21·22]]}
(SUPPORTS? GREEN RED)@{[[19,20]], [[21:22]]}
(SUPPORTS? GREEN BLUE)@{[[0:30]]}
(SUPPORTS? BLUE MOVING)@{[[13:24]]}
(SUPPORTS? BLUE RED)@{[[12:30]]}
(CONTACTS? RED BLUE)@{[[12·19]], [[20:21]], [[22:30]]}
(CONTACTS? GREEN BLUE)@{[[0:30]]}
(ATTACHED? MOVING RED)@{[[0:24]]}
(ATTACHED? RED BLUE)@{[[19:20]], [[21:22]]}
```

FIG. 8A

```
(PICK-UP MOVING RED BLUE)@([[0,11],[25,33])}
(UNSTACK MOVING RED BLUE GREEN)@([[0,11],[25,33])}

(SUPPORTED? MOVING)@{[[11·23]]}
(SUPPORTED? RED)@{[[0:36]]}
(SUPPORTED? BLUE)@{[[0:36]]}
(SUPPORTS? MOVING RED)@{[[23:36]]}
(SUPPORTS? RED MOVING)@{[[11:23]]}
(SUPPORTS? RED BLUE)@{[[13:14]]}
(SUPPORTS? GREEN MOVING)@{[[13:14]]}
(SUPPORTS? GREEN RED)@{[[13:14]]}
(SUPPORTS? GREEN BLUE)@{[[0:36]]}
(SUPPORTS? BLUE MOVING)@{[[11:23]]}
(SUPPORTS? BLUE RED)@{[[0:25]]}
(CONTACTS? MOVING RED)@{[[34:36]]}
(CONTACTS? RED BLUE)@{[[0:13]], [[14:24]]}
(CONTACTS? GREEN BLUE)@{[[0.13]], [[14:36]]}
(ATTACHED? MOVING RED)@{[[11:33]]}
(ATTACHED? RED BLUE)@{[[13:14]]}
(ATTACHED? GREEN BLUE)@{[[13·14]]}
```

FIG. 8B

```
(PICK-UP MOVING RED GREEN)@{[[0,9],[17,46])}
(PUT-DOWN MOVING RED BLUE)@{[[17,35],[46,52])}
(MOVE MOVING RED GREEN BLUE)@{[[0,9],[46,52])}

(SUPPORTED? MOVING)@{[[9·15]]}
(SUPPORTED? RED)@{[[0·52]]}
(SUPPORTED? BLUE)@{[[35:46]]}
(SUPPORTS? MOVING RED)@{[[17:46]]}
(SUPPORTS? MOVING BLUE)@{[[35:46]]}
(SUPPORTS? RED MOVING)@{[[9.15]]}
(SUPPORTS? RED BLUE)@{[[35:46]]}
(SUPPORTS? GREEN MOVING)@{[[9.15]]}
(SUPPORTS? GREEN RED)@{[[0:17]]}
(SUPPORTS? BLUE RED)@{[[46:52]]}
(CONTACTS? RED GREEN)@{[[0·17]]}
(CONTACTS? RED BLUE)@{[[46:52]]}
(ATTACHED? MOVING RED)@{[[9:46]]}
(ATTACHED? RED BLUE)@{[[35·46]]}
```

FIG. 8C

```
(PUT-DOWN MOVING RED GREEN)@{[[57,68],[68,87])}
(PUT-DOWN MOVING GREEN BLUE)@{[[18,35],[41,47])}
(STACK MOVING RED GREEN BLUE)@{[[57,68],[68,87])}
(ASSEMBLE MOVING RED GREEN BLUE)@{[[18,35],[68,87])}

(SUPPORTED? MOVING)@{[[10:18]], [[47.57]]}
(SUPPORTED? RED)@{[[57:87]]}
(SUPPORTED? GREEN)@{[[11 87]]}
(SUPPORTED? BLUE)@{[[35·41]]}
(SUPPORTS? MOVING RED)@{[[57 68]]}
(SUPPORTS? MOVING GREEN)@{[[11·41]]}
(SUPPORTS? MOVING BLUE)@{[[35·41]]}
(SUPPORTS? RED MOVING)@{[[10 18]], [[47 57]]}
(SUPPORTS? RED GREEN)@{[[11.16]]}
(SUPPORTS? GREEN RED)@{[[68.87]]}
(SUPPORTS? GREEN BLUE)@{[[35 41]]}
(SUPPORTS? BLUE GREEN)@{[[41.87]]}
(CONTACTS? RED GREEN)@{[[68:87]]}
(CONTACTS? GREEN BLUE)@{[[41 87]]}
(ATTACHED? MOVING RED)@{[[11.16]], [[49 68]]}
(ATTACHED? MOVING GREEN)@{[[11 41]]}
(ATTACHED? GREEN BLUE)@{[[35 41]]}
```

FIG. 8D

```
(PICK-UP MOVING RED GREEN)@{[[0,19],[23,50])}
(PICK-UP MOVING GREEN BLUE)@{[[22,58],[62,87])}
(UNSTACK MOVING RED GREEN BLUE)@{[[0,19],[23,50])}
(DISASSEMBLE MOVING RED GREEN BLUE)@{[[0,19],[62,87])}

(SUPPORTED? MOVING)@{[[19:22]]}
(SUPPORTED? RED)@{[[0·50]]}
(SUPPORTED? GREEN)@{[[0 87]]}
(SUPPORTED? BLUE)@{[[58:62]]}
(SUPPORTS? MOVING RED)@{[[23·50]]}
(SUPPORTS? MOVING GREEN)@{[[58:87]]}
(SUPPORTS? MOVING BLUE)@{[[58.62]]}
(SUPPORTS? RED MOVING)@{[[19:22]]}
(SUPPORTS? GREEN MOVING)@{[[19:22]]}
(SUPPORTS? GREEN RED)@{[[0:23]]}
(SUPPORTS? GREEN BLUE)@{[[58.62]]}
(SUPPORTS? BLUE GREEN)@{[[0:58]]}
(CONTACTS? RED GREEN)@{[[0.23]]}
(CONTACTS? GREEN BLUE)@{[[0:58]]}
(ATTACHED? MOVING RED)@{[[19:50]]}
(ATTACHED? MOVING GREEN)@{[[58.87]]}
(ATTACHED? GREEN BLUE)@{[[58.62]]}
```
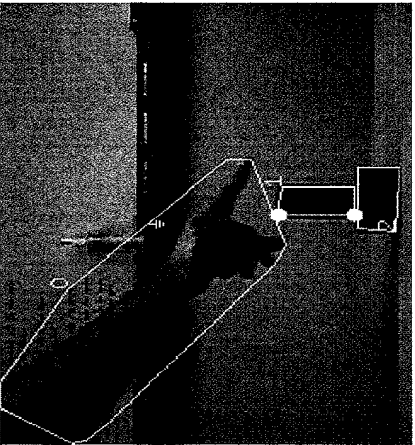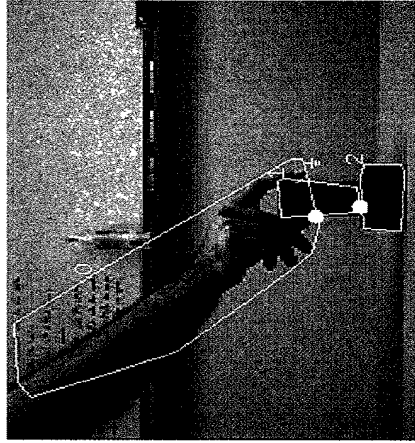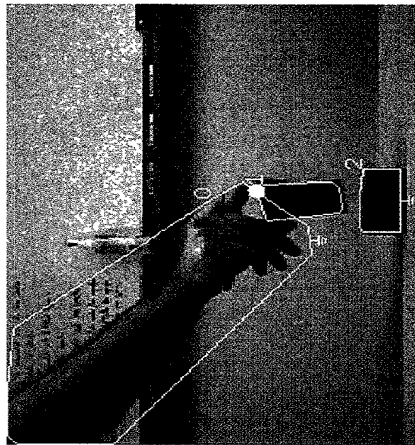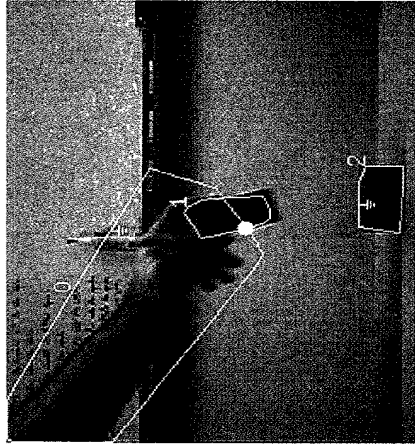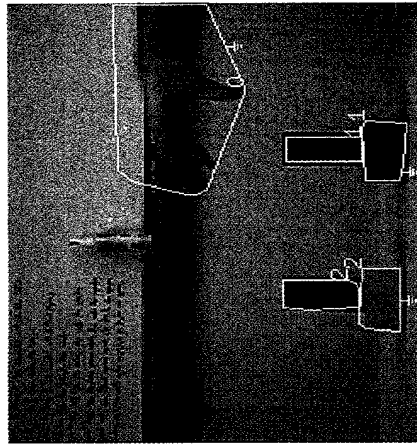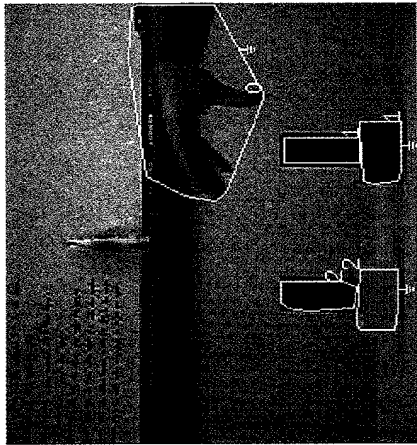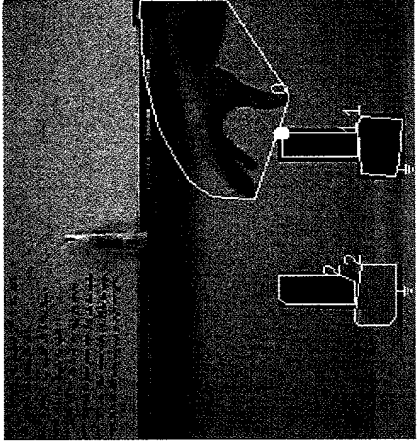
FIG. 8E
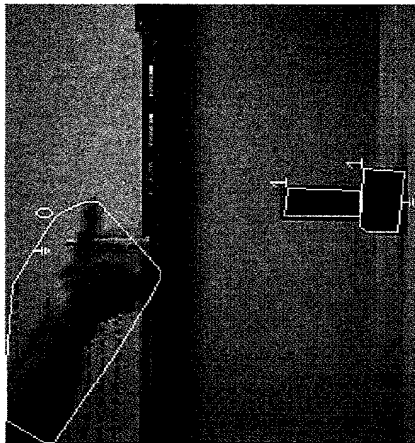
frame 5
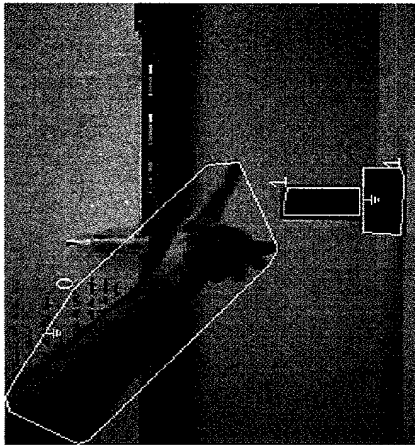
frame 10

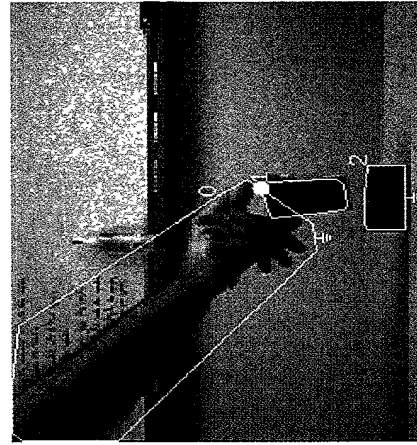frame 11

frame 17

frame 18

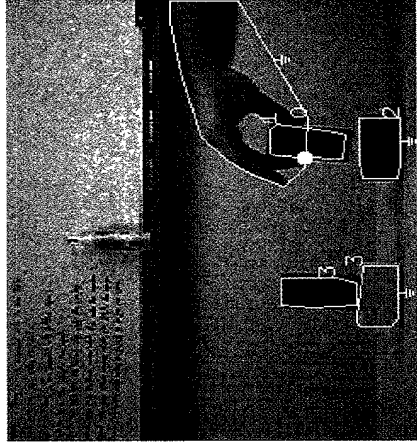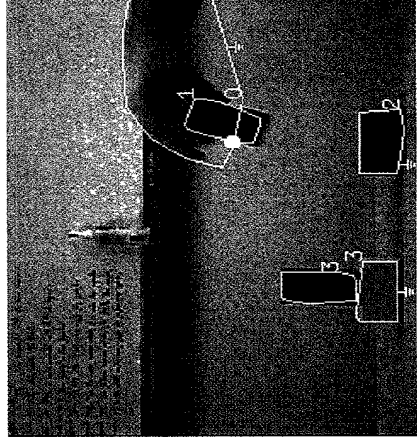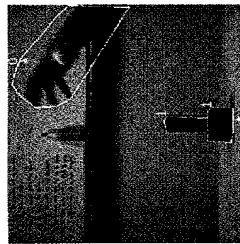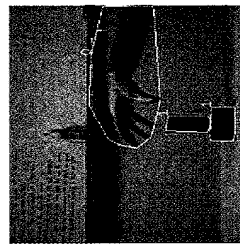frame 22

FIG. 9A

frame 6   frame 7   frame 8

frame 18   frame 19   frame 24
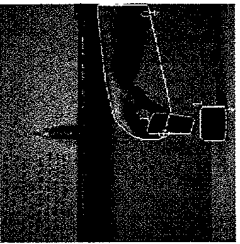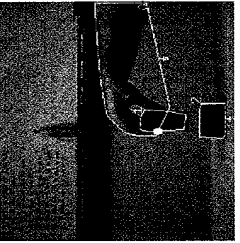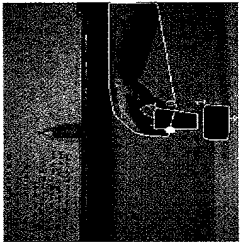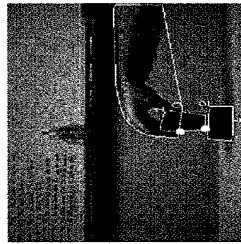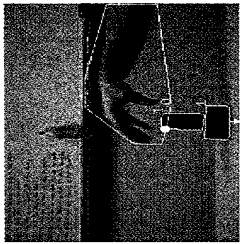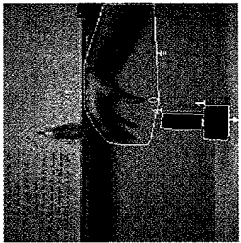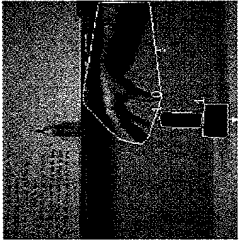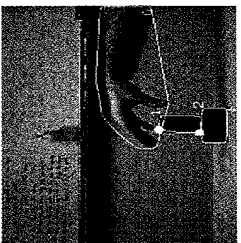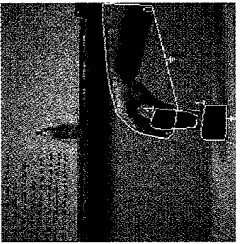
FIG. 9B

frame 4
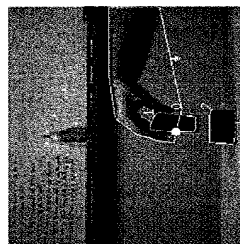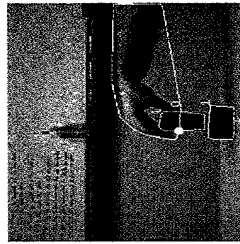
frame 8
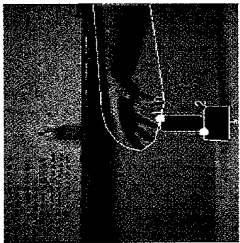
frame 9

frame 18

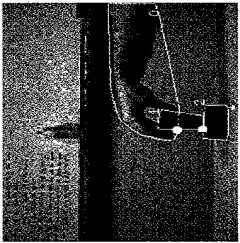frame 19
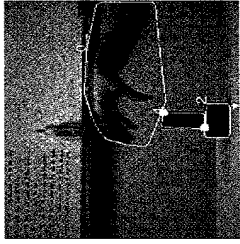
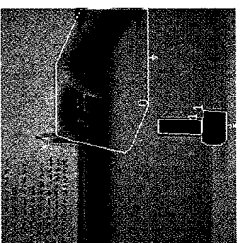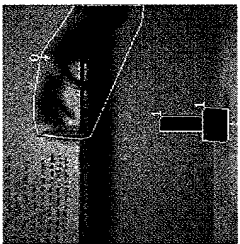frame 44

frame 45
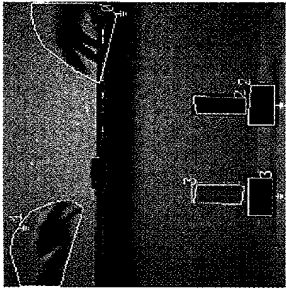
frame 51
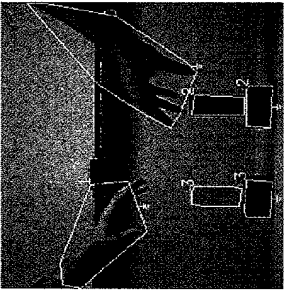
frame 52

frame 69

frame 70
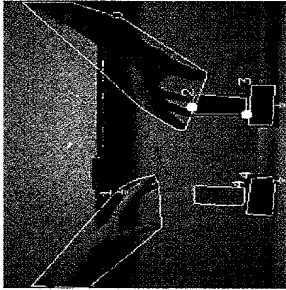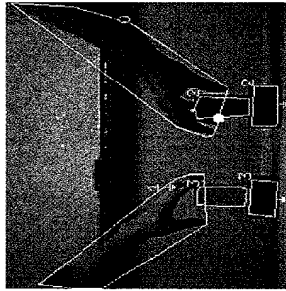
frame 77

frame 78

frame 102

frame 103

frame 109

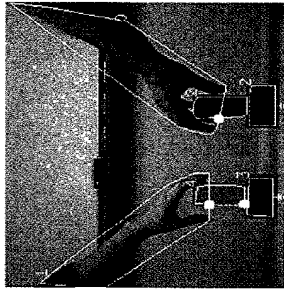frame 110

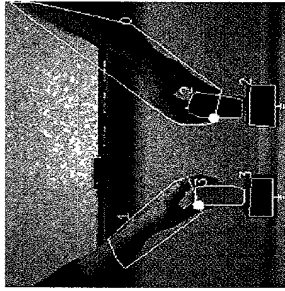frame 111

FIG. 9C

frame 0   frame 5   frame 6   frame 10
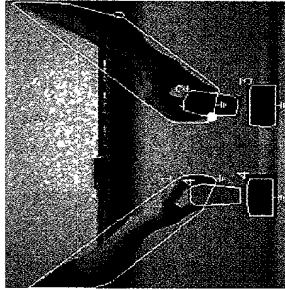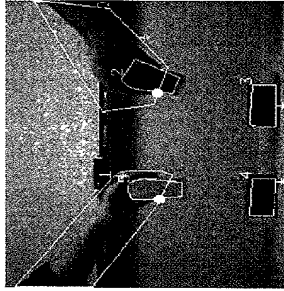
frame 11   frame 15   frame 16   frame 21

FIG. 9D

(PICK-UP MOVING RED GREEN)@{[[0,11],[18,30]]}

(SUPPORTED? RED)@{[[0:30]]}
(SUPPORTED? GREEN)@{[[11:18]]}
(SUPPORTS? MOVING RED)@{[[11·30]]}
(SUPPORTS? MOVING GREEN)@{[[11:18]]}
(SUPPORTS? RED GREEN)@{[[11:18]]}
(SUPPORTS? GREEN RED)@{[[0:11]]}
(CONTACTS? RED GREEN)@{[[0:11]]}
(ATTACHED? MOVING RED)@{[[11:30]]}
(ATTACHED? RED GREEN)@{[[11:18]]}

FIG. 10A

(PICK-UP MOVING RED GREEN)@{[[0,8],[19,30]]}

(SUPPORTED? MOVING)@{[[8·19]]}
(SUPPORTED? RED)@{[[0:30]]}
(SUPPORTED? BLUE)@{[[0.30]]}
(SUPPORTS? MOVING RED)@{[[19·30]]}
(SUPPORTS? RED MOVING)@{[[8:19]]}
(SUPPORTS? GREEN MOVING)@{[[8:19]]}
(SUPPORTS? GREEN RED)@{[[0:19]]}
(SUPPORTS? YELLOW BLUE)@{[[0:30]]}
(CONTACTS? RED GREEN)@{[[0:10]], [[16 19]]}
(CONTACTS? BLUE YELLOW)@{[[0.30]]}
(ATTACHED? MOVING RED)@{[[8:30]]}
(ATTACHED? RED GREEN)@{[[10:16]]}

FIG. 10B

(PICK-UP MOVING RED GREEN)@{[[52,70],[78,102]], [[0,9],[19,44]]}
(PUT-DOWN MOVING RED GREEN)@{[[19,44],[52,70]], [[78,102],[110,117]]}

(SUPPORTED? MOVING)@{[[9:18]], [[44:52]], [[70·77]], [[102·110]]}
(SUPPORTED? RED)@{[[0:117]]}
(SUPPORTS? MOVING RED)@{[[18:44]], [[78 102]]}
(SUPPORTS? RED MOVING)@{[[9:18]], [[44·52]], [[70.77]], [[102·110]]}
(SUPPORTS? GREEN MOVING)@{[[9:18]], [[44.52]], [[70.77]], [[102.110]]}
(SUPPORTS? GREEN RED)@{[[0·19]], [[44:78]], [[102.117]]}
(CONTACTS? RED GREEN)@{[[0:9]], [[13:18]], [[46:70]], [[106:117]]}
(ATTACHED? MOVING RED)@{[[9.52]], [[70:110]]}
(ATTACHED? RED GREEN)@{[[9:13]], [[70.76]], [[104·106]]}

FIG. 10C

(PICK-UP MOVING RED GREEN)@{[[0,6],[16,22]]}
(PICK-UP MOVING YELLOW BLUE)@{[[0,12],[17,22]]}

(SUPPORTED? MOVING)@{[[6:16]]}
(SUPPORTED? MOVING)@{[[12.15]]}
(SUPPORTED? RED)@{[[0:22]]}
(SUPPORTED? YELLOW)@{[[0:22]]}
(SUPPORTS? MOVING RED)@{[[16:22]]}
(SUPPORTS? MOVING YELLOW)@{[[17 22]]}
(SUPPORTS? RED MOVING)@{[[6:16]]}
(SUPPORTS? GREEN MOVING)@{[[6 16]]}
(SUPPORTS? GREEN RED)@{[[0:16]]}
(SUPPORTS? BLUE MOVING)@{[[12·15]]}
(SUPPORTS? BLUE YELLOW)@{[[0 17]]}
(SUPPORTS? YELLOW MOVING)@{[[12·15]]}
(CONTACTS? RED GREEN)@{[[0:15]]}
(CONTACTS? BLUE YELLOW)@{[[0:17]]}
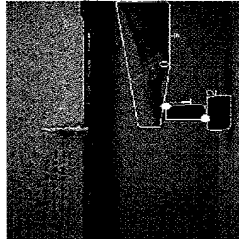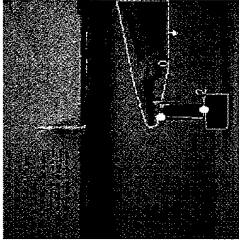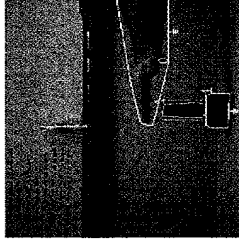(ATTACHED? MOVING RED)@{[[6:22]]}
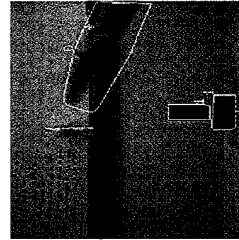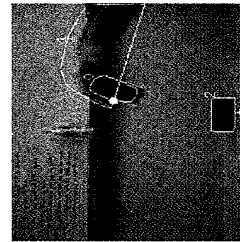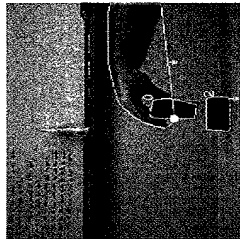(ATTACHED? MOVING YELLOW)@{[[12·22]]}

FIG. 10D
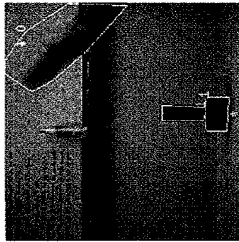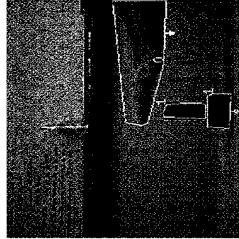
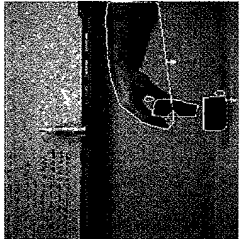frame 0 | frame 6 | frame 7 | frame 12 | frame 13 | frame 18
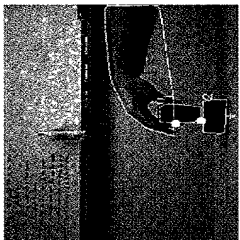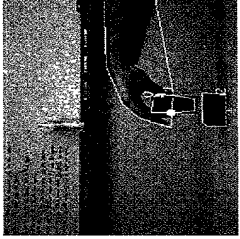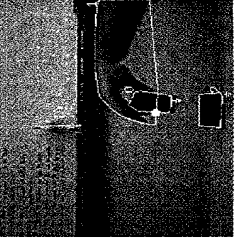
FIG. 11A

frame 4 | frame 11 | frame 12 | frame 18 | frame 19 | frame 21

FIG. 11B

```
(SUPPORTED? RED)@{[[0:25]]}
(SUPPORTED? GREEN)@{[[7:13]]}
(SUPPORTS? MOVING RED)@{[[7:13]]}
(SUPPORTS? MOVING GREEN)@{[[7:13]]}
(SUPPORTS? RED GREEN)@{[[7:13]]}
(SUPPORTS? GREEN RED)@{[[0:7]], [[13:25]]}
(CONTACTS? RED GREEN)@{[[0:7]], [[13:25]]}
(ATTACHED? MOVING RED)@{[[7:13]]}
(ATTACHED? RED GREEN)@{[[7:13]]}
```

FIG. 12A

```
(SUPPORTED? RED)@{[[0:19]]}
(SUPPORTED? MOVING)@{[[13:31]]}
(SUPPORTS? RED MOVING)@{[[13:31]]}
(SUPPORTS? MOVING RED)@{[[0:13]]}
(SUPPORTS? GREEN RED)@{[[12:19]]}
(SUPPORTS? GREEN MOVING)@{[[13:19]]}
(ATTACHED? RED MOVING)@{[[0:31]]}
(ATTACHED? RED GREEN)@{[[13:19]]}
```

FIG. 12B